Evaluation of security features in new design U.S. currency

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ABSTRACT

The first new design of U.S. currency in almost 70 years was introduced in March 1996 with the Series 1996 $100 note. The new design, which will be carried through to lower denominations, incorporates new overt features for use by the public. With introduction of the new $50 note in late 1997 and production of the $20 note in 1998, evaluation of the new features is in order. Since the $100 note has now been in circulation for well over a year, sufficient data is available to carry out a meaningful analysis. This report summarizes that analysis.

For the analysis, two approaches are taken. The first is to characterize and quantify the gamut of counterfeits that have been generated, from copiers and printers to traditional lithographic versions. Overall quality as well as effectiveness of individual features will be rated. Results from the new design will be compared with those from the older designs.

The other involves analysis of macroscopic counterfeiting trends as a function of year and series, to probe the impact of changes in the currency, both subtle and obvious. Understanding these trends can aid in the development of effective strategies to minimize counterfeiting over the long run.

Keywords: counterfeit deterrence, counterfeits, currency features, effectiveness, evaluation

1. BACKGROUND

1.1. The imaging challenge

The goal of the electronic imaging industry is to make faithful reproductions of all intended subjects as accurately, economically and directly as possible. According to the industry ideal, on presenting the subject image to the copier system, a single operation would result in an exact reproduction in terms of resolution, color and image quality, all for a reasonable price.

The goal of the banknote industry is to ensure that banknotes cannot be reproduced, not even poorly, but, in the event of violations, to facilitate enforcement.

Although these goals are at direct cross-purposes, both the imaging and banknote industries have responded to the challenge of satisfying both goals with some innovative approaches. The electronic imaging industry has developed and installed systems in output equipment that allow identification of the originating machine in each copy. Parallel systems recognize certain characteristics of banknotes and stop the machines from making legible copies of them.

The banknote industry has responded to the challenge by designing into banknotes an array of multidimensional features that are difficult to reproduce using standard imaging techniques. In fact, within the last decade nearly every major currency has undergone design changes to incorporate such features, which are generally characterized by reflective, optically variable or transmissive properties.

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1.2 U.S. response

In keeping with the rest of the banknote industry, the U. S. has also, for the first time since 1929, seen fit to make major changes to its currency design to bolster it against modern imaging technology[1]. The $100 note, introduced in March, 1997, first in the new series, has now been in circulation for over a year and a half. The second in the New Currency Design (NCD) series, the $50 note, was introduced last fall, in October 1997. Lower denominations will follow in the near future. However, before the NCD series is completed, work will be started on the next generation design. Evaluation of the effectiveness of the current design might provide valuable guidance in the development of these future designs. To that end, a study was undertaken to identify general trends in counterfeiting activity and to determine how well the new features in the NCD series have functioned against counterfeiting. These analyses were accomplished by systematically examining and evaluating all types of counterfeits received and registered at the U.S. Secret Service, which holds sole responsibility for enforcement against counterfeiting of U.S. currency. General trends in counterfeiting, based on the statistical database maintained by the Secret Service since 1986, were also reviewed. Results are summarized in this report.

2. FEATURE EVALUATION

2.1 Evaluation approach

The main overt features (Figure 1) in the new currency design are the following: larger, off-center portrait, registered portrait watermark, color-shifting ink, enhanced security thread, intaglio microprinting, concentric fine-line patterns. Individual counterfeits were examined and compared to real notes (an archival "specimen" note and a circulated note). Portrait quality was not assessed directly, but is reflected in the overall quality impression. Figure 2 shows a representative offset counterfeit of the new note in both reflected and transmitted light.

For comparison, representative samples of the earlier, threaded series notes (referred to as Advanced Countefeit Deterrence or ACD notes) were also evaluated. One batch examined was from the time period immediately following introduction of the first ACD notes ($100's) in 1991. This group serves as a baseline to show up any trends possibly related to design changes in the currency. The other batch examined was received at the Secret Service during the early introduction phase of the ACD notes (after March, 1996). This group serves as a calibration for the current level of technology used by counterfeiters.

The characteristics of each overt feature from each counterfeit examined were evaluated in turn and results tabulated for analysis according to the associated New Counterfeit (NC) number, which is assigned by the Secret Service to any incoming, ostensibly new counterfeit received. For instance, for each counterfeit, the color match, metallic character and shifting properties of the attempted color-shifting ink was assessed against the genuine feature. For some characteristics, the attempts at counterfeiting the features were rated poor, fair or good relative to resemblance to the genuine. This more detailed analysis (in contrast to simple presence or absence) provides additional insight into the intentions and abilities of the counterfeiters and the effectiveness of the feature. In all, by the end of November 1997, 56 NC numbers had been assigned to 1996 series $100 counterfeits. These counterfeits, mostly offset, do not as a rule include toner or ink jet counterfeits, which are handled separately.

2.2.1 Registered portrait watermark

The registered portrait watermark is an overt, paper-based feature that supplements the security thread already introduced in the ACD currency design. In the U.S. notes as seen in transmitted light, the watermark fully fills the window formed by the surrounding intaglio of the face and back images. The watermark image itself, based on the same art work as the portrait, is formed of soft but clearly defined lines which blend smoothly into the paper. In reflected light, the image is not readily discernible.

Result: In 43 (77%) of the counterfeits, some attempt was made to simulate the watermark, generally by printing with an opaque or light-colored ink. Nearly 4 out of 5 of those attempts gave poor (and sometimes *very* poor) results. Many attempted watermarks were very difficult to make out because they were so faint in transmitted light. In two samples, the watermarks, which poorly resembled the genuine to start with, were readily visible in reflected light, but *invisible* in transmitted light. In two other cases, the image was extremely sharp - and therefore was obviously not genuine. Other attempted watermarks were almost humorous: completely out of register, grossly under-sized or blatantly visible in reflected light, with little resemblance to the portrait or to the genuine watermark. Figure 3 shows a genuine and a typical counterfeit watermark in transmitted light.

2.2.2. Color-shifting ink

The color-shifting ink feature serves as an overt, image-based characteristic that can be readily explained to and used by the general public. The ink used in U.S. currency is characterized by a distinctive green color when viewed normal to the print surface which shifts abruptly and cleanly to a flat black as the viewing angle becomes oblique. The genuine ink has a metallic characteristic as well and is transparent to UV illumination. Thus the counterfeiter is challenged to mimic both the base and shift colors, the metallic character and the print quality of the genuine image.

Results: Out of the 56 notes examined, only 6 (11%) achieved any type of shift. In 25 cases, some attempt was made to achieve metallic character with metallic or iridescent flakes, inks or other materials. Most of the greens achieved by the counterfeiters, with or without metallic or shifting properties, were poorly matched to the genuine. Two samples showed fairly good shifts and color matches, but in every case, the counterfeit was readily distinguishable under close scrutiny or low-power magnification. In one case, a degree of shifting was exhibited but the print quality was *extremely* poor.

2.2.3 Enhanced security thread

The security thread in the ACD series, in the same position in all denominations, was intended only to serve as an overt feature for general use, with no specific secondary characteristics. In the NCD series, the enhanced thread is denomination-specific in both position and fluorescent properties. For the $100 note, the thread is located between the portrait and the Federal Reserve Seal and fluoresces red in UV light. To those with normal vision, the graphics, unchanged from the previous series, are crisp and legible under backlighting.

Results: Simulation of the thread was attempted in 46 (86%) of the counterfeits examined. In three of those samples, no attempt was made at graphics and only an opaque strip was apparent. Of the remaining 43, 16 were judged fair or good and 30 were poor. Most attempted threads suffered from illegible or excessively faint graphics, excessive opacity of the strip or visibility in reflection. The majority of the simulations were printed, but in a few cases an actual strip was used. The same counterfeit that had the grossly misplaced watermark also had the thread (just an opaque stripe) in completely the wrong place (to the left of the seal). In 6 samples, there was some evidence of red (or orange-red) fluorescence. In a few other cases, the thread fluoresced yellow or bright blue. At least five of the threads actually absorbed in the UV, appearing as very black stripes.

In contrast, during the first year after the introduction of the threaded ACD series in 1991, few attempts were made to simulate the thread but when attempted, results were fairly credible. This observation led to the evaluation of the ACD counterfeits contemporary to the NCD counterfeits examined. In this cursory evaluation, the majority of notes had simulated threads, suggesting that introduction and widespread distribution of the threaded series has upped the ante for the counterfeiter, possibly contributing to the overall decline in counterfeits over the last year. Further evaluation of the available data to track the prevalence of thread simulation might yield further insight.

2.2.4 Intaglio microprinting

The microprinting in the new series is not the same as in the ACD series. In the ACD series, the microprinting surrounded the portrait with the text "The United States of America." In the new design, two forms of microprint are used. The smaller, lighter form (the "USA 100" version) appears as repeating text reading "USA 100" that fills the macroscopic lower lefthand denominating numeral in such a way that each element fits perfectly within its boundaries. The larger, bolder form (the "collar" version), "The United States of America" is inscribed along the collar fold of Franklin's coat.

Result: Figure 4 shows genuine and typical counterfeit microprinting. Unexpectedly, in 47 (84%) of the counterfeits, the "USA 100" microprint was completely illegible and obviously no attempts had been made to enhance it. In two samples the microprint was 'very legible and judged good; in three, the legibility was fair but obviously not the same as in genuine notes. In one sample, the whole tint of microprinting had been reworked with characters of a size, font and spacing different from genuine. In another case, the tint area where the microprinting should be was printed in gray, but with no attempt to replicate the microprinting.

Although a surprising number (22) of the counterfeits did not have legible "collar" microprinting, many did. In most cases the distinction from genuine was still obvious, with poor quality lettering, but 6 were actually rated good. For comparison, in the ACD counterfeits, the rate of even poorly legible microprint is about 23%, roughly comparable to that of the "USA 100" microprint in the new design.

2.2.5 Concentric fine-lines

The concentric fine-line patterns behind the portrait on the face and the vignette on the back of the note were introduced into the NCD series primarily to induce image corruption during color copying and half-tone imaging.

Results: Since most counterfeits (74% by nominal value[2]) are produced using traditional offset, little such corruption was seen in this set of counterfeits. In a couple of cases, half-toning was used either alone or in combination with offset and disruptive effects were observed.

2.2.6 Color copies and ink jet counterfeits

In FY 97, the office machine and ink jet counterfeits together comprised about 25% of the total value of counterfeits. As mentioned earlier, counterfeits of this type are not registered and filed in the same way as the traditional counterfeits. Instead they are evaluated and returned to the originating office. Although a few examples of very well executed counterfeits of this type have come to light, in the vast majority of cases, the quality of the copies is poor, with no attempts made to simulate any of the overt features such as watermark, thread or color-shifting ink. The biggest issue with this type of counterfeit is the increasing volume of such counterfeits emerging.

2.2.7 Overall quality

The overall quality of the counterfeits examined was surprisingly mediocre. A few cases were notable exceptions, but in each case at least one overt feature was absent or poorly executed. One counterfeiter apparently worked very hard to achieve a color shift but was unable to reproduce either type of microprinting or successfully simulate the thread and watermark. Another did a respectable job overall, but made such a crisp and well-defined watermark that it was not deceptive. A few others were of a high enough overall quality to warrant a closer look but did not exhibit a color shift or legible microprinting, or the security fibers were drawn in orange or green (not in the same notes). On examining the early and more recent control groups of ACD counterfeits, this quality level was found to be consistent. If anything, the ACD style notes were in poorer condition, many of them being physically degraded or soiled. Perhaps the expectation of cleaner genuine notes leads the counterfeiter to produce cleaner bogus notes.

2.3 Effectiveness of new features

In the main, the new features in the NCD series - as well as the original thread and microprinting - are functioning as they were intended to individually and as a group. Examined individually, the counterfeited features are generally easily recognized as counterfeit; in cases in which one or more is reasonably executed, one or more of the others is not. The overall quality of counterfeits is sufficiently poor that casual scrutiny by a moderately well-informed recipient would lead to suspicion, and hopefully rejection of the counterfeit or alerting of the authorities. Based on the observations from this study of counterfeits of the new currency, the best defense against counterfeiting is still an educated public that is familiar with the features in genuine currency.

3. COUNTERFEITING TRENDS

3.1 General

In its 1993 report on counterfeit deterrent features, the National Research Council (NRC) Committee on Next-Generation Currency Design proposed a model for the impact of introducing new counterfeit deterrent features on counterfeiting activity[3]. In this model, two scenarios are proposed. In the first, counterfeiting of a given feature increases to a threshold of tolerance as a function of time from introduction. At the threshold, the notes with the old features are no longer acceptable to the public and new features are introduced; counterfeiting of the older features falls as counterfeiting of the new begins to rise to its own threshold. The Committee suggests that the level of counterfeiting could be reduced by systematically introducing new features before the threshold in counterfeiting is reached.

To test this hypothesis, trends in counterfeiting levels of different series of notes were examined. To establish the levels of counterfeiting, the numbers of new counterfeit (NC) identifiers per denomination and series were tracked. Although this method does not give a perfect measure of counterfeiting activity, it does provide a baseline of activity for purposes of comparison. Use of this method avoids to a large extent the artificial distortion of the numbers due to seizure of a large volume of a particular type of counterfeit. It also avoids the distinction between notes which have been passed into circulation and those which were seized before passing, thus giving a better indication of the actual activity of the counterfeiters, independent of law enforcement issues.

The results were unexpected and supported the Committee's hypothesis in a way not anticipated. In Figure 5, the number of NC's for a given series is plotted against the number of years from series date (an approximation of the issue date) in which the NC's were assigned. A clear pattern emerges: each series experiences a peak in counterfeiting 4-6 years after issuance. The implication is that a change in the series itself is enough to force the counterfeiters to change their targets. This situation is likely influenced by the frequency of changes in series of U.S. currency and by the rate at which the notes in circulation turnover. The counterfeiters may become increasingly reluctant to risk scrutiny of their handiwork as a series wanes in concentration in circulation.

3.2 Impact of NCD $100 Introduction

Further analysis of the data suggests that the introduction of the new currency series has indeed influenced counterfeiting activity. If the numbers of NC's are plotted by denomination, the response of the counterfeiters to the introduction of a new design series is evident, as seen in Figures 6 and 7, which show the data by fiscal year for the $100 and $50 notes. As seen in these figures, the pattern for the $100 notes is fairly consistent, with peaks observed every few year as the new series are introduced. However, a distinctive drop in the level of counterfeiting, both overall (**Sum pre-ACD, ACD, NCD Series**) and for only the ACD notes (**Sum ACD Series**), is seen in response to the issuance of the NCD $100 note. As the following table shows, the total number of NC's decreased from 1715 in 1996 to 1186 in 1997, roughly a 30% decrease. A similar abrupt drop in counterfeiting of the pre-ACD notes (Series 1981 - 1988A) occurred after the introduction of the ACD $100 note with security thread and microprinting in 1991. In this case, the level of pre-ACD counterfeiting dropped 26%, from 1354 to 1004 new counterfeits registered in the ensuing year. These two observations taken together suggest that introduction of new features in currency has a mitigating effect on counterfeiting. Tracking these effects as further changes are made to currency could help clarify an appropriate strategy to new feature introduction.

Counterfeits by Series and Year

Series	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1981	268	493	174	140	114	152	100	81	87	66	46	26
1985	31	135	218	1036	869	519	506	290	231	130	112	82
1988				0	67	512	747	599	427	315	206	123
1988A						0	1	34	49	11	13	23
1990						1	72	308	610	729	1077	503
1993										0	259	427
1995											2	2
1996											4	91
ACD + NCD						1	72	308	610	729	1342	1023
Sum pre-ACD	299	628	392	1176	1050	1183	1354	1004	794	522	377	254
Sum ACD						1	72	308	610	729	1338	932
Sum pre-ACD, ACD, NCD	299	628	392	1176	1050	1184	1426	1312	1404	1251	1715	1186

4. SUMMARY

The systematic evaluation of all the counterfeits of the Series 1996 (NCD) $100 notes has elucidated several issues related to counterfeiting and the introduction of new features in currency. Primary among these is confirmation that the best defense against counterfeiting is a public that is sufficiently knowledgeable about the currency to recognize the characteristics of the suite of features intended for their use Results for the most part were fairly predictable: the new features are functioning as intended. Although a few ingenious and careful counterfeiting efforts have produced fairly convincing individual features, none has successfully executed the full suite of overt features. The new U.S. currency design has upped the ante for counterfeiters, increasing their work load to approximate the visual features of the genuine note.

The less expected observations relate to what are arguably the most and least sophisticated features: the color-shifting ink and the microprinting. That almost half the counterfeiters attempted and a few achieved some level of color shift in the lower right hand feature may be due to its prominence in the new design and popularity with the public. Although all instances were readily discernible from the genuine on scrutiny, some additional layer (overt or covert) of complexity in the feature design might enhance its effectiveness in the long term.

On the other end of the spectrum, microprinting, especially the finer, lighter " USA 100" was surprisingly robust against reproduction and was largely ignored by the counterfeiters. However, since the accessible resolution range is ever extending, the continued status of this feature should be closely monitored so its use can be discontinued when it is no longer effective.

In light of these observations, the continued message to the public should be to become familiar with the characteristics that define a genuine note and then to judge a proffered note based on the full suite of characteristics, not just on a single feature or test. First and foremost, the base level print characteristics (intaglio versus offset or modern reprographic methods) distinguish the genuine from the counterfeit. In almost every case, even to the untrained eye, inspection under low magnification and comparison with a genuine note will quickly point up a counterfeit.

Regarding macroscopic trends in counterfeiting, the introduction of both the threaded ACD series and the more recent NCD design has led to apparent downturns in counterfeiting activity, especially of the $100 notes. In the case of the NCD introduction, a concomitant increase of counterfeiting of old-style $50 notes was also observed. This increase may be a direct result of the introduction of the new $100's, or it may be a reflection of increased use of $50 notes in circulation. Further analysis and continued tracking of these potential trends are warranted. More detailed analysis of the circulating banknote pool by series prevalence might clarify some of the observed trends, since counterfeiting activity is apparently closely tied to series issuance. Close scrutiny of the counterfeiting activity and success at feature compromise as a function of external factors may provide guidance in directing counterfeit deterrence strategies for the future. In light of the rapid and accelerating pace of technology, such strategies are surely required -- introduction of the NCD series represents only a single step in the ongoing effort to ensure the continued protection of U. S. currency against counterfeiting.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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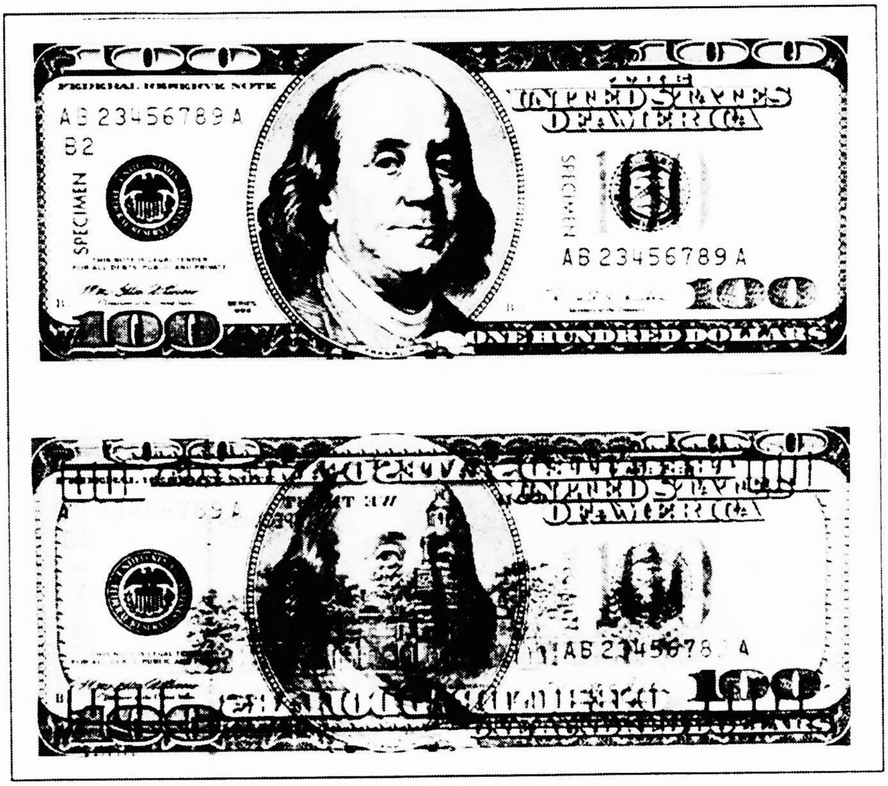
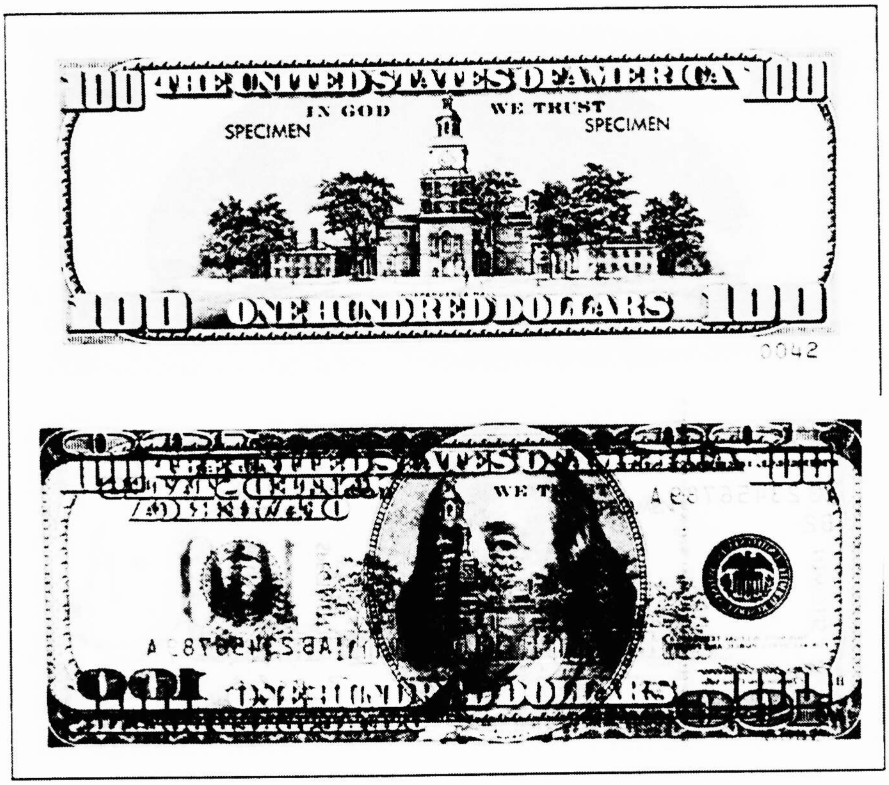
2. Secret Service statistics for FY 1997; personal communication
3. National Materials Advisory Board, *Counterfeit Deterrent Features for the New Currency Design*, pp. 92-96., Washington DC, National Academy Press, 1993.

FIGURE 1. Genuine NCD $100 banknote.

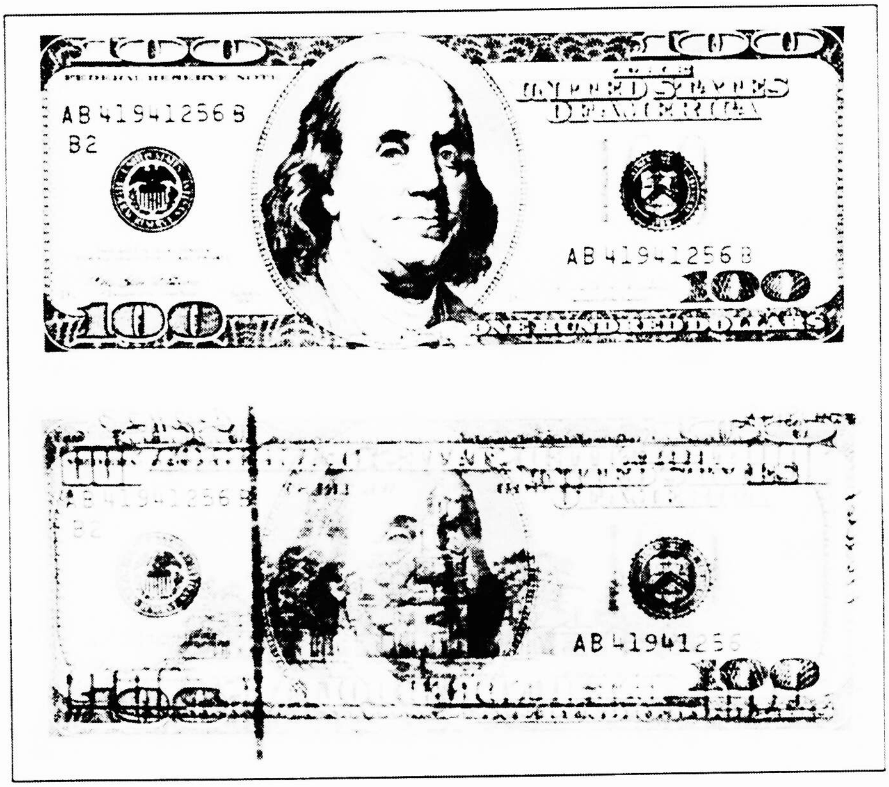


a) Face in reflected and transmitted light

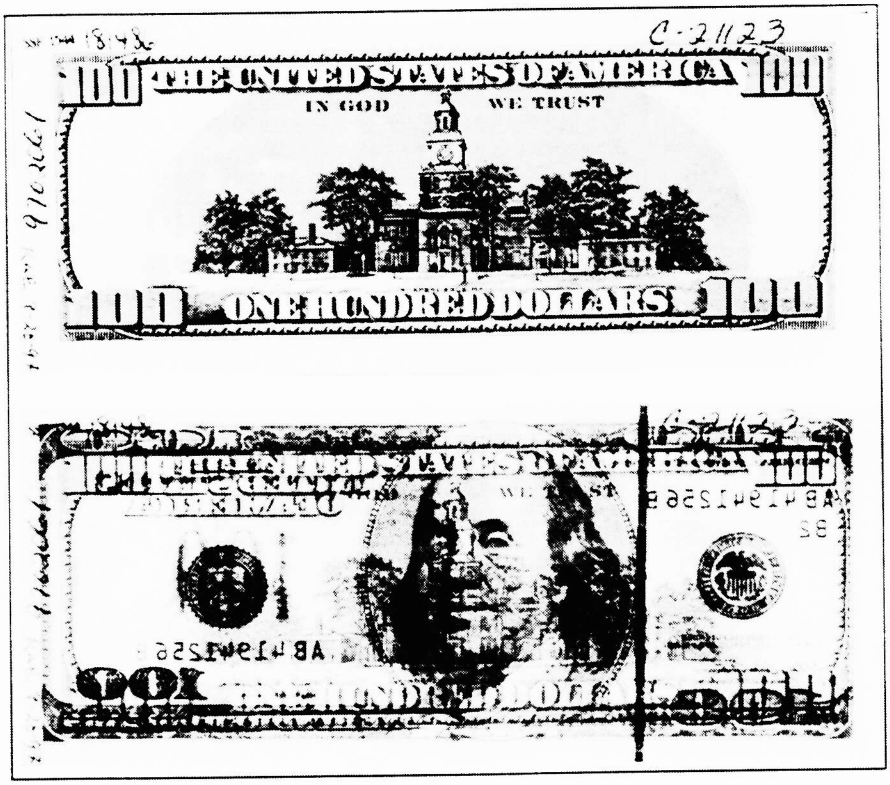


b) Back in reflected and transmitted light

FIGURE 2. Representative Counterfeit of NCD $100 banknote

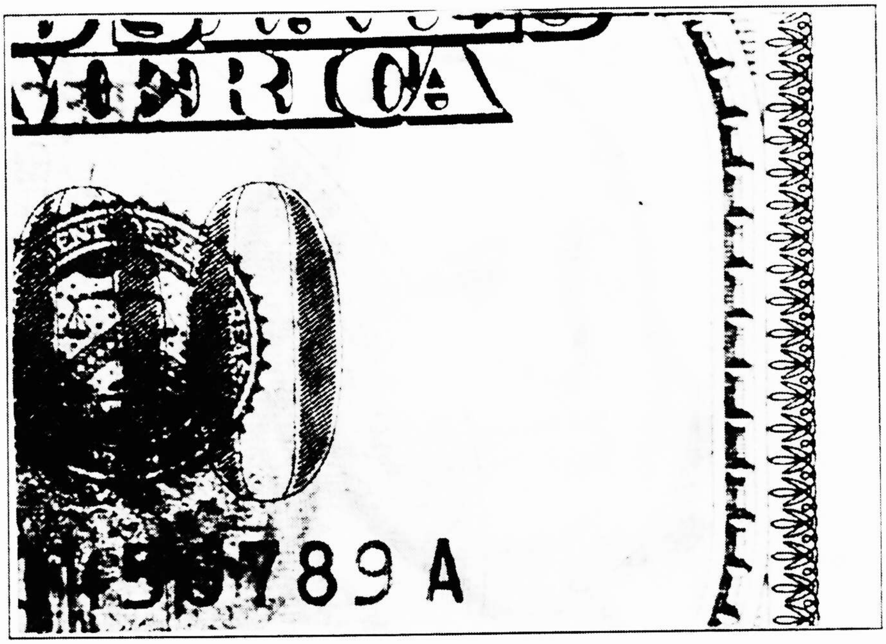


a) Face in reflected and transmitted light

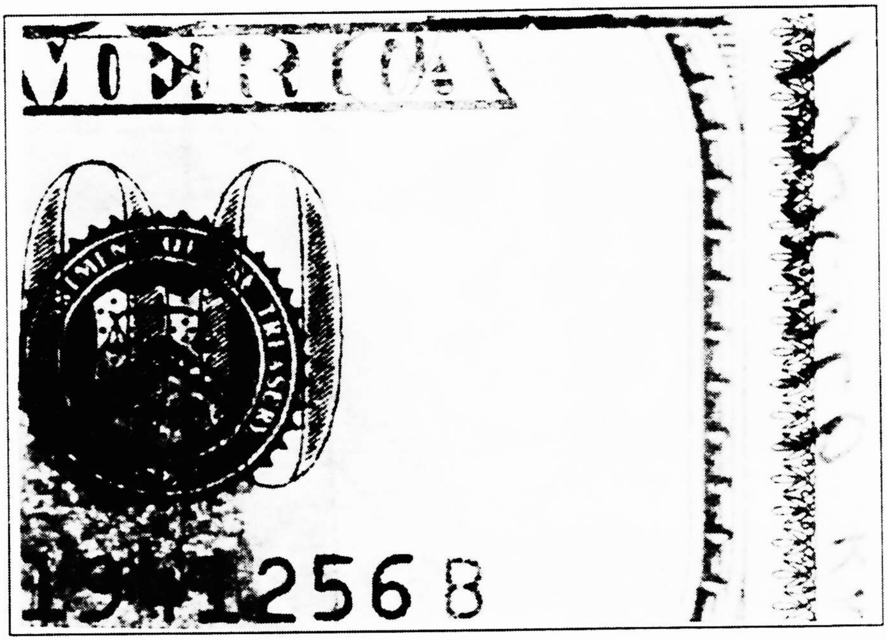


b) Back in reflected and transmitted light

FIGURE 3. Watermarks in transmitted light

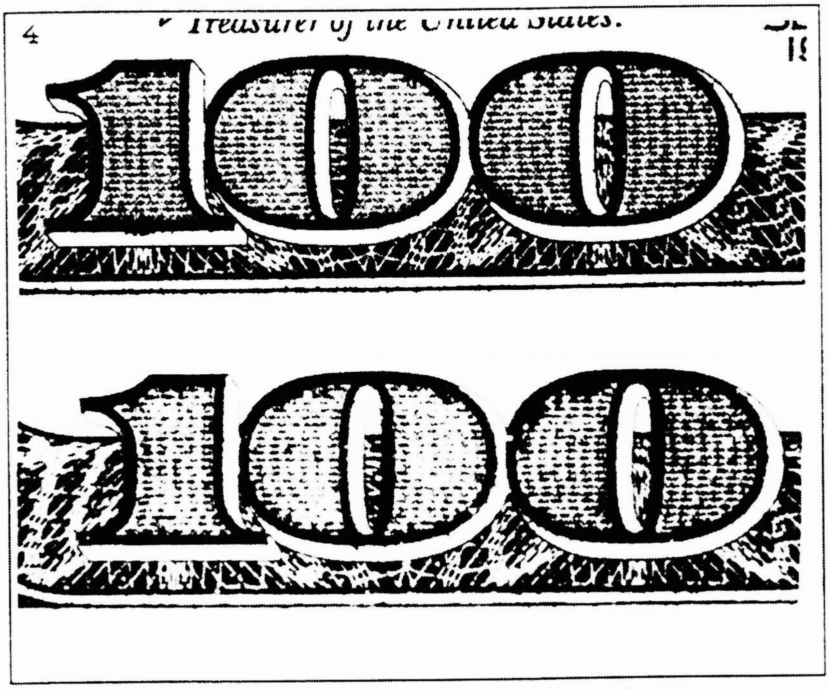


a) Genuine watermark

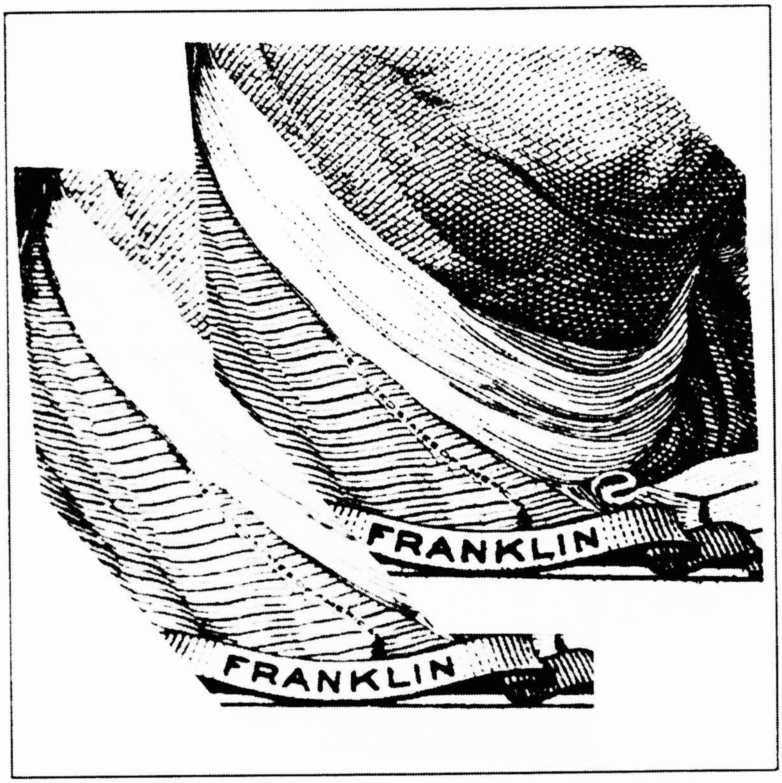


b) Counterfeit

FIGURE 4. Genuine and counterfeit (a) "USA 100" and (b)"collar" microprinting

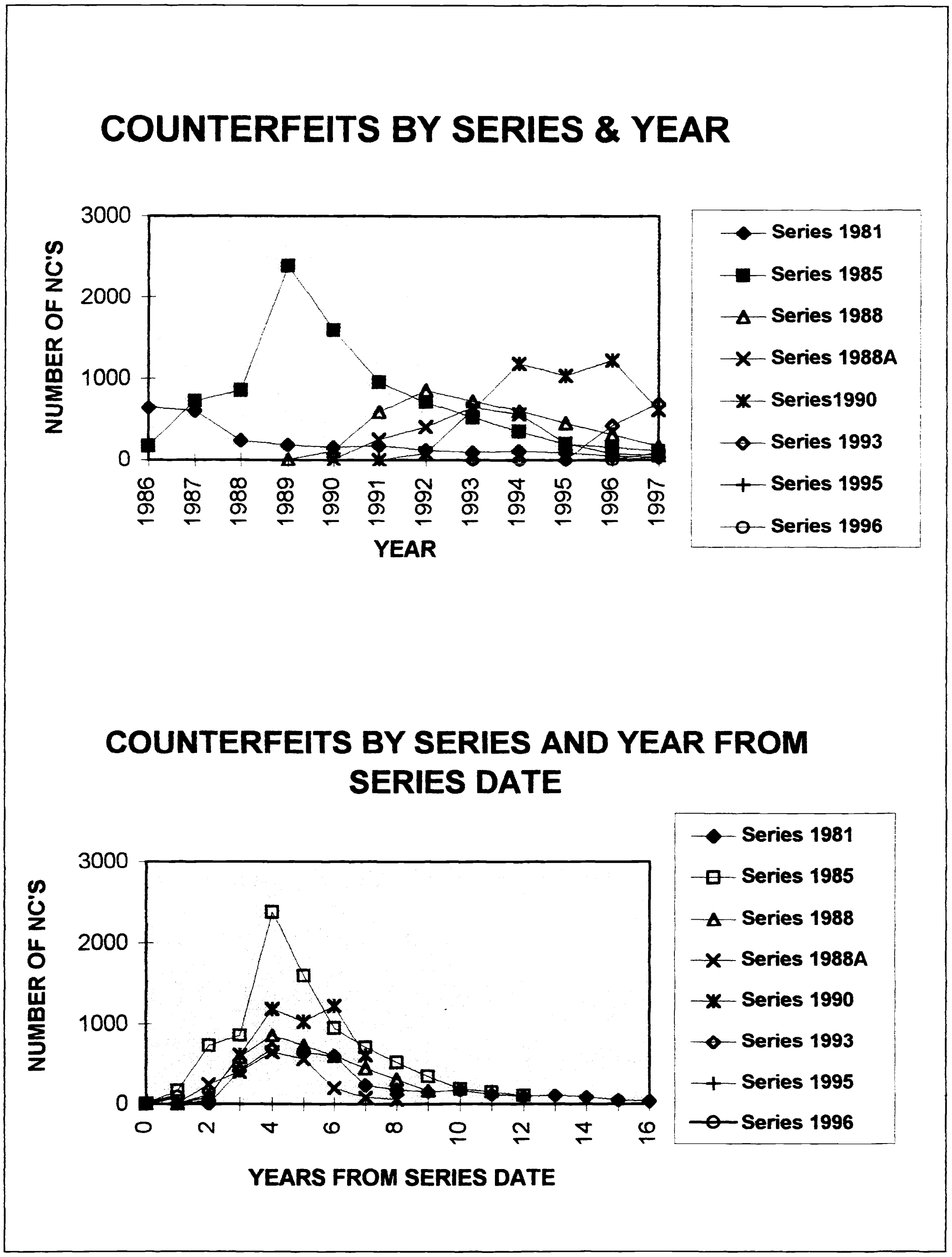


a) "USA 100" microprinting: Genuine - top; counterfeit - bottom



b) "Collar" microprinting: Genuine - top; counterfeit - bottom

FIGURE 5. Counterfeits - all denominations $10 and above


COUNTERFEITS BY SERIES & YEAR

COUNTERFEITS BY SERIES AND YEAR FROM SERIES DATE

FIGURE 6. Counterfeit $100's

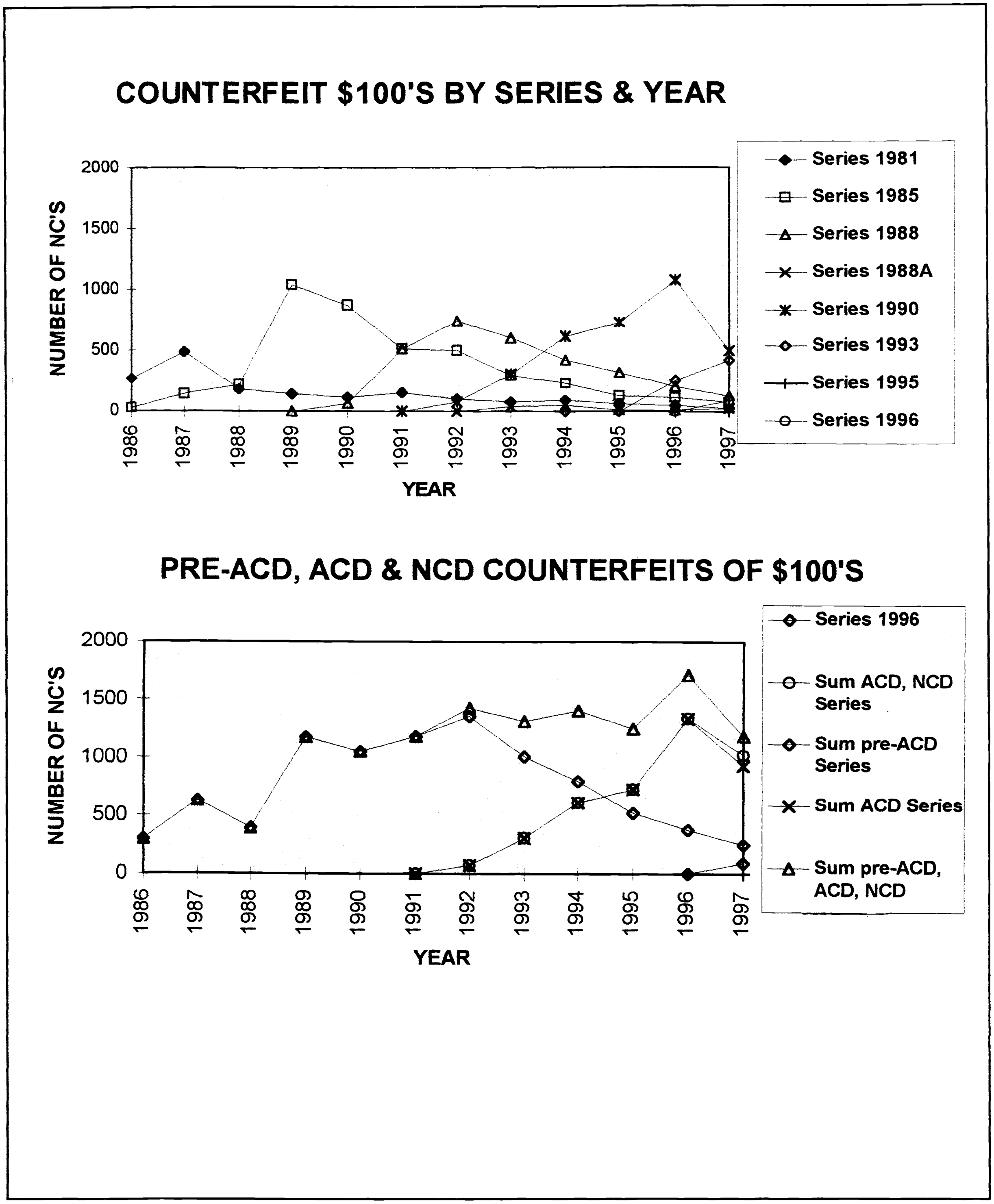


FIGURE 7. Counterfeit $50's